Reprinted from the JOURNAL OF THE AMERICAN OIL CHEMISTS' SOCIETY, Vol.56, No.3, Pages:367-374

Some Important Fermented Foods of Mid-Asia, the Middle East, and Africa

C.W. HESSELTINE, Northern Regional Research Center, Federal Research, Science and Education Administration, U.S. Department of Agritulture, Peoria, IL USA

ABSTRACT

Other speakers in this Symposium discussed fermented foods of China, Japan, and Southeast Asia; I will describe several other fermented foods that are very important in Mid-Asia, the Middle East, and Africa. These fermentations, unlike those of the Orient, use bacteria and yeasts instead of filamentous fungi. They are acid products prepared from cereals traditionally grown in the areas, notably sorghum, millet, maize, and wheat. Since African, Middle Eastern, and Mid-Asian fermented foods are often supplemented with milk or legumes, the final protein content may be rather good. For example, bouza and ogi have a protein content of 11 to 13% on a dry weight basis, while in kishk the protein content is about 23.5%. In the Indian food idli, the protein average content is 15.3%. Advantages of acid fermented food products are:

- Preservation of the fermented product because of the organic acids produced. These acid products are sometimes dried to give even longer keeping times.
- They are high in fiber content.
- Because some are dried, they may be transported easily from one place to another.
- They probably have enhanced nutritional value because of the vitamins formed during production.
- They are foods used for centuries and therefore culturally acceptable.
- Unlike some of the other fermented foods discussed, they are used as main course dishes rather than flavoring agents.

An example of a Mideast food prepared by lactic acid bacteria is tarhana of Turkey, which consists of parboiled wheat meal, yogurt, and added vegetables which are then allowed to ferment and then sun dried. In Central and South Africa, kaffir beer (Bantu beer) is made by malting maize or sorghum, fermenting with lactic acid bacteria to give a low pH, and then finally fermenting with a yeast. The protein content ranges from 8.5 to 11.9%. A second commercially produced product is mahewu (magou) prepared by the natural fermentation of maize to produce an acid mash which is then dried. This food has a content of 7-9% protein.

INTRODUCTION

When we think of food fermentations, aside from those we encounter daily such as cheese and bread, we think of those strange and exotic products like soy sauce, soybean paste, and tempeh made in China, Japan, and the East Indies. However, in some parts of the world, huge amounts of fermented food are produced and used in the daily diet of the people and are an essential part of their nutrition. The foods made by yeast and bacterial fermentations which I will describe very briefly are those produced in Pakistan, India, the Middle East, and Africa below the Sahara Desert. Time restricts the descriptions to only five such foods. Although these regions are quite far apart in geography, culture, and religion, traditional fermented foods show some close similarities such as:

- Most fermented foods are based on cereals such as millet, sorghum, maize, and wheat.
- They are supplemented with a source of protein either of animal or plant origin. In the Middle East this is usually a milk product, whereas in India and Pakistan it is a locally grown legume.
- The microorganisms used are typically those present in or on one of the ingredients and are selected by adjusting the fermentation conditions. Except for the industrialized Bantu beer and mahewu processes, all the fermentations are self-inoculated.
- Most of the foods depend on fermentation in a liquid menstrum, as contrasted to the Far East fermentations on moist solid substrates.

Although some of the fermentations are called beers, they are not beer in the sense of Western Europe or America. The African beers are characterized by opaque liquids or semisolids with low or no alcohol, containing a high percentage of solids, including cells of microorganisms.

- The product is almost always acidic.
- Yeast and bacteria (mainly lactic bacteria) are the only organisms that carry out the fermentations. So far as I know, molds are present only as chance contaminants.
- The fermentation time is short – a matter of hours, not weeks or months.
- Except for Bantu beer, none of the fermentations has been scientifically studied on the scale that shoyu or miso have been studied in the Orient.

There are at least eight reasons for using a fermented process in the production of these acid foods.

1. In the fermentations carried out by lactic bacteria, organic acids such as lactic and acetic acids are formed that act as preservatives in inhibiting the growth of harmful bacteria because they lower the pH. In the Arab world, this is combined with drying to give an even longer keeping time. One has only to visit the Indian villages along the Ganges to be impressed with the need for some kind of preservation. The high temperature and high humidity, coupled with unsanitary conditions and lack of education concerning food handling, are ideal for food spoilage.

TABLE I

Vitamin Content (μg/100 g) of Sorghum Beer in 1975 (1)[a]

Vitamin	Range	Average
Thiamine	39-60	47
Riboflavin	28-43	35
Nicotinic acid	340-350	400

[a]Whole ground sorghum was added as adjunct.

TABLE II

Fermented Foods of Pakistan, India, the Middle East, and Africa

Name	Area or country	Substrate	Microorganism	Use of food	Reference
			Mid Asia		
Idli	India (especially South India)	Rice, dehulled	Yeast and bacteria	Pancakes	2
		Blackgram	*Leuconstoc mesenteroides*		3
Dhokla	India	Wheat, bengalgram	Unknown	Fermented batter is steamed	4
Panjabi waries	India	Blackgram	*Candida* and *Saccharomyces* sp.	Spicy condiment	3
Papadam	India	Blackgram	*Candida* and *Saccharomyces* sp.	Condiment	3
Ambali	India	Ragi flour, rice, and buttermilk	Unknown	Sour food	4
Khaman	India	Bengalgram	Unknown	Batter steamed and seasoned	4,5
Rabdi	India	Maize and buttermilk	Unknown	Sour corn mush	4
Doza (Dosai)	India	Rice, black gram	Yeast and bacteria	Highly seasoned griddle-like pancake	3,4
Kanji	India	Rice and carrots	*Hansenula anomala* var. *anomala*	Sour liquid added to vegetables	3,4,6
Jalebies	Nepal, India, Pakistan	Wheat flour	*Saccharomyce* sp.	Pretzel-like, syrup-filled confections	3
Nan (khab-z)	India, Pakistan, Afghanistan, Iran,	Unbleached wheat flour	Unknown	Leavened bread	7
Kenima	Nepal, Sikkim, and Darjeeling District of India	Soybeans	Unknown	Tempeh-like	7
Darassun	Mongolia	Millet	Unknown	Drink	7
Thumba (Bojah)	West Bengal	Millet	*Endomycopsis fibuliger*	Mildly acidic alcoholic drink	(Ullstrup, personal com., 1961)
			Middle East		
Tarhana	Turkey	Parboiled wheat meal and yogurt (2:1)	Lactics	Dried, used in soup	8
Bagni	Caucasus	Millet	Unknown	Drink	7
Injera	Ethiopia	Teff *(Eragrostis tef)*	*Candida guilliermondii*	Bread-shaped like pancakes	9
Busa	Tartars of Krim, Turkestan	Rice or millet and sugar	*Lactobacillus* and *Saccharomyces*	Fermented drink	10
Bouza	Egypt	Wheat	Unknown	Thick acidic liquid with an alcoholic odor	11
Kishk (Kushuk-Iranian name)	Egypt, Syria, and Arab world	Wheat, milk	Lactic acid bacteria	Dried balls; dissolves rapidly in water	12
			Africa below Sahara Desert		
Finger millet beer	Africa	Finger millet	Yeast	Diluted paste	13
Munkoyo	Africa	Millet, maize, or kaffir corn plus crushed roots of Munkoyo *(Eminia holubii)*	Unknown	Drink	13
Maize beer	Africa	Maize	Unknown	Thick liquid	13
Manioc beer	Africa	Manioc	Unknown	Thick liquid	13
Maize, manioc beer	Africa	Maize, manioc	Unknown	Thick liquid	13
Maize-manioc bulrush, millet beer	Africa	Maize, manioc, bulrush millet	Unknown	Thick liquid	13
Maize, finger millet sorghum beer	Africa	Maize, finger millet and sorghum	Unknown	Thick liquid	13
Gari	West Africa, Nigeria	Cassava roots	*Geotrichum candidum* and *Corynebacterium* sp.	Almost pure starch with sour taste, Eaten with bean-flour or fish	14,15

TABLE II – continued

Fermented Foods of Pakistan, India, the Middle East, and Africa

Name	Area or country	Substrate	Microorganism	Use of food	Reference
Ogi	Dahomey, Nigeria	Maize	Molds and bacteria	Fermented cake boiled and eaten hot; if cooked on banana leaves then called agidi	13,16
Burukutu	Savannah regions of Nigeria	*Sorghum vulgare* and cassava	Lactics and *Candida* sp., *S. cerevisiae*	Creamy liquid with suspended solids	17
Pito	Nigeria	Guinea corn or maize or both	Unknown	Beverage	(Ekundayo, personal com., 1978)
Dawadawa (uri)	Savannah of Africa, Nigeria	African locust bean *Parkia filicoidea*	Unknown	Made into small balls and dried	8,14
Lafun	Nigeria, West Africa	Cassava	Bacteria	Staple food as a paste	14
Kenkey	Ghana	Maize	Unknown	Fermented steamed mush	13
Merissa	Sudan	*Sorghum bicolor*	*Saccharomyces* sp.	Liquid	(Dirar, personal com., 1966)
Sorghum beef [Bantu beer, kaffir beef, leting, joala, utshivala, mqomboti (made of sorghum) igwele]	South Africa	Maize, sorghum	Lactics and yeast	Thick acidic drink	18
Mahewu (Magou)	South Africa	Maize	*Lactobacillus delbrueckii* and other lactics	Sour, nonalcoholic beverage	19
Leting (low alcohol)	Basutos	(see sorghum beer)	Unknown	Acid beverage	20
Joala (high alcohol)	Basutos	(see sorghun, beer)	Unknown	Acid beverage	20
Utshwala (high alcohol)	Zulu, Swaziland	(see sorghum beer)	Unknown	Acid beverage	20
Igwele	Zulu	(see sorghum beer)	Unknown	Beverage	20
Mqomboti-Joala	Cape Colony	Kaffir corn	Unknown	Beer	20
Ting	Pedi (tribe of Basutos)	Meal	Unknown	Porridge	21
Metogo	Pedi	Kaffir corn, maize, and kaffir millet	Unknown	Nonintoxicating beverage	21
Mabjalwa	Pedi	Kaffir corn or kaffir millet	Unknown	Beverage	21
Chickwangue	Congo	Cassava	Bacteria	Mainly starch, toxic material removed	14
			Other Areas		
Kaanga-kopuwai (Kaanga-pirau, Koanga-wai)	New Zealand's Maori	Maize	Unknown	Gruel	22
Braga	Romania	Millet	Unknown	Acidic Alcoholic drink	23
Fermented rice (Sierra rice)	Ecuador	Unhusked rice	*Aspergillus flavus* and *A. candidus* and *Bacillus subtilis*	Brownish yellow dry rice	24
Pozol	Southeastern Mexico	Maize	Complex of molds, yeast, and bacteria	Fermented dough diluted with water is drunk as a basic food by Indians in Mexico	25

TABLE III

Protein Reported from Some Fermented Foods of India, Middle East, and Africa

Name	Protein (g/100 g)	Reference
Bouza	11.8-13.1	11
Kishk	23.5	12
Khaman	21.9-22.4	5
Idli	13.9-14.1 and 15.36	2,5
Gari	0.9	15
Fermented rice	8.8	24
Ogi	9.1-11.5	26
Bantu beer	8.5-11.9	27
Mahewu	7-9	28
KenKey	9.7-11.6	29

2. Need for fiber in the diet is now widely recognized; because whole cereals are used in these foods, fiber content is quite high. Studies among the Bantu tribes show that Western diseases, such as diverticulosis, colonic irritation, colon cancer, and other chronic diseases of the gastrointestinal tract are almost unknown.
3. Many of the peoples in these areas were formerly nomads; thus, the sundried fermented products can be transported easily from one place to another. Also, the products can be preserved in a dry state for months or even years as a food reserve in case of drought or famine.
4. Fermented products have enhanced nutritional value because of vitamins and enhanced digestibility. Novellie (1), using modern vitamin analysis, has studied sorghum beer. Table I gives the vitamin content based on an examination of serveral samples.
5. Unlike some of the other fermented foods discussed in this symposium, such as shoyu for flavoring fish and vegetables, these fermented products are used as main course dishes.
6. These foods have been prepared as far back as recorded history and, therefore, are culturally acceptable. Most Indian Hindus can eat only nonamimal foods; therefore, products made from indigenous cereals and legumes are acceptable.
7. Because of the varied ingredients, mixed microorganisms, and addition of spices and salt, the flavor of the fermented foods are varied and help to overcome the monotony of eating local plant products.
8. Many areas of the world I am talking about are desperately short of cooking fuel. One has only to travel in India to see the cakes of cow manure drying in the sun to be used for cooking to realize that foods must be prepared with a minimum of fuel. The odor and smoke of burning cow manure in steaming Bombay in the early morning made a vivid impression on me.

Table II lists some 50 fermented foods of these regions. My files contain references to at least that many more.

Where data are available, protein contents of foods listed in Table II are presented in Table III. It should be noted that the protein content varies greatly.

Rather than attempt to describe a number of the foods in Table II, I will concentrate on only five of those above which have the most published information.

IDLI

This is a steamed fermented food made from two parts rice and one part black gram dal (dehulled *Phaseolus mungo)* and is used typically as a breakfast food. Black gram is also called urd beans in the United States. Idli is a popular fermented food of south India; the fermentation inoculum is the natural flora in the starting materials. According to Ramakrishnan (4), this food goes back to at

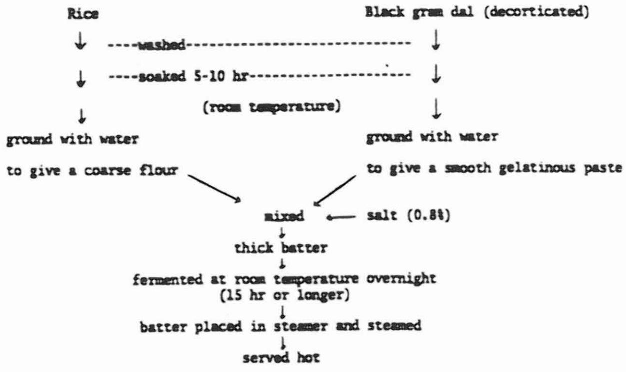

FIG. 1. Idli fermentation.

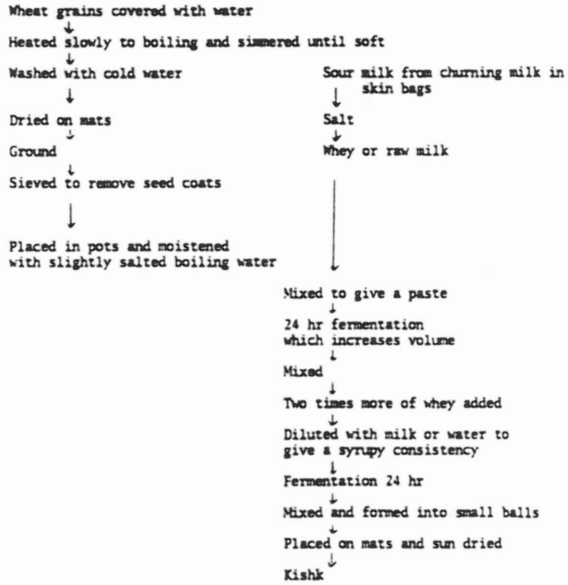

FIG. 2. Kishk fermentation.

least 1100 AD. Figure 1 is a flow diagram of the idli fermentation.

The steamed food is very soft and spongy in texture and possesses a sour flavor like steamed sour-dough bread (30). The amounts of rice to black gram may vary from 4:1 to 1:4. In some instances, other ingredients are added for flavor, such as cashew nuts, ghee, pepper, and ginger. The amount of soaking water can vary from 1.5 to 2.2 times the dry weight of the black gram dal or the rice. Steinkraus et al. (30) found that soybeans or common beans (*Phaseolus vulgaris)* could be substituted for black gram to form a satisfactory idli. The fermentation will vary depending on the temperature and the ingredients, but generally Steinkraus et al. (30) found 20-22 hr to be satisfactory. In India, sour buttermilk or yeast is sometimes added. The two most important changes during fermentation are leavening and acidification. The above authors found that the batter volume increased 1.6-3.1 times and the initial pH of 6.0 fell to 4.3-5.3. Soluble solids generally showed a slight increase, whereas soluble nitrogen decreased. The bacterial count ranged from 10^3 to 10^5/ml and rose to 10^8 to 10^9/ml at the end of 20-22 hr. The predominant organism producing acid and gas was *Leuconostoc mesenteroides.* Other bacteria were *Streptococcus faecalis* and *Pediococcus*, and these probably came from the black gram since parboiled rice is often used.

The nutritive value of idli was reported by van Veen et al. (2) using rats. Their idli contained 15.3% protein, with a PER of 1.84 as compared to 1.79 for the same unfermented and untreated ingredients. They conclude that

Maize soaked in lukewarm water for 1-2 days
↓
Wet milled
↓
Sieved to remove fiber, hulls, and much of germ
↓
Filtrate allowed to sour
↓
White sour sediment marketed as wet cake wrapped in leaves

FIG. 3. Ogi fermentation.

the fermentation apparently did not improve the PER or the digestibility.

KISHK

Kishk is a wheat-milk mixture commonly found throughout the Arab world. The following account is taken from the recent studies of Morcos et al. (12). Typically the milk used is the surplus that accumulated during the winter and is stored in earthenware containers to be used in the summer. The process is shown in Figure 2.

Sometimes spices such as pepper or cumin are added to the milk. The microorganisms are those present in the milk, and counts show large numbers of *Lactobacillus plantarum*, *L. casei*, *L. brevis*, yeast, and *Bacillus subtilis*. Usually the kishk is heated in an oven to improve its keeping quality. The balls are brownish in color and have a rough surface and a hard texture. When placed in water, they rapidly break up.

Morcos et al. (12) reported analyses of five samples of commercial kishk which showed a protein content of 23.5%. Its composition based on the mean of five samples was: 7.8% Moisture, 23.5% Protein, 6.9% Fat, 59.0% Carbohydrate, 2.5% Fiber, and 8.1% Ash.

The mineral content was 55 mg/100 g Calcium, 410 mg/100 g Phosphorus, and 3.8 mg/100 g Iron.

The amino acid content of kishk based on mg/g N is shown below.

Phenylalanine	310
Threonine	220
Isoleucine and leucine	1050
Histidine	155
Arginine	310
Valine	335
Tryptophan	65
Lysine	310
Tyrosine	255
Cystine	110
Methionine	120

In the dry state, kishk may be kept for long periods of time.

OGI

Ogi, a fermented sour maize product, is typical of a number of products with different tribal names found all through Black Africa. Ogi is the name given by the Yorubas in western Nigeria to the fermented maize product. Prepared inoculum is not used, but rather the selection of a part of the natural flora on the maize is depended on for the starter. Akinrele (16), an authority on fermented foods of this part of Africa, states that ogi is widely used as the first native food given to babies at weaning and is a major breakfast cereal for adults. The following account is based mainly on three papers by Akinrele (16) and Banigo and Muller (26,31). The low energy requiring process is illustrated in Figure 3.

The ogi cake may be diluted with water to give a liquid with 8-10% total solids. This is boiled and called ogidi, or the cake may be cooked into a stiff gel (eko) and made into a meal.

Akinrele (16) states that in Nigeria the variations in this process are mainly in times for steeping and souring. Steeping varies from one to three days, and souring time depends on the production of a good sour flavor as determined by taste. This author found that at three days, the predominant microorganisms were *Lactobacillus plantarum*, *Aerobacter cloacae*, and yeasts; no molds were present. The initial pH of 5.6 fell to between 3.5 to 3.85 at the end

TABLE IV

Nutrients in Ogi (16)

Analysis	Unfermented ogi	Mixed culture of[a] *Lactobacillus* and *Aerobacter*	Traditional fermented ogi
Total N (%)	1.38	1.54	1.49
Amino N (%)	0.04	0.02	0.05
Nonprotein N(%)	0.10	0.07	0.06
Thiamine (mg/100 g)	0.06	0.04	0.11
Riboflavin (mg/100 g)	0.07	0.14	0.08
Niacin (mg/100 g)	0.68	1.15	0.85
Folic acid (mg/100 g)	0.05	0.05	0.05
Pantothenic acid (mg/100 g)	0.04	0.03	0.01

[a]Experimentally simulated traditional ogi fermentation.

TABLE V

Proximate Composition of Cereals and Ogi Samples[a] (31)

	Corn	Corn Ogi[b]	Sorghum	Sorghum Ogi[b]	Millet	Miller Ogi[b]	Corn	Corn Ogi[c]
Moisture	10.8	41.0	11.8	41.0	12.4	41.3	10.7	47.4
Crude protein	12.0	11.5	11.3	11.3	10.3	9.1	7.2	3.6
Fat	4.4	3.9	3.9	2.7	4.8	7.5	5.0	1.6
Crude fiber	1.46	1.08	1.52	1.75	1.48	1.47	1.72	0.23
Carbohydrate (by difference)	81	83	82	84	82	81	85	93
Ash	1.49	0.39	1.68	0.45	1.77	0.56	1.37	0.19
Cals	410	414	407	405	411	430	413	410

[a]As a percentage on dry basis except moisture.
[b]Wet-milled with Waring blendor-Colloid mill combination.
[c]Wet-milled with a pestle and mortar.

Maize meal

↓

Mixed in warm water to give 8% solids

↓

Cooked at 15 psi for 15 min

↓

Cooled

↓

Inoculated (5% wheat flour and adapted pure culture of *Lactobacillus delbrueckii*)

↓

Incubate 30-35 C with wheat. If *L. delbrueckii*, incubate at 45 C

↓

Fermentation 36 hr with mixing only at the beginning of fermentation

↓

Heat for 10-15 min at 7 lb/sq in.

↓

Spray or drum dry

FIG. 4. Mahewu fermentation.

of three days. Steeping for one day in warm water was sufficient for the production of lactic acid bacteria. The principal acid is lactic, and the only amylase was formed by Corynebacteria. Acetic acid and traces of butyric acid were also found.

Akinrele (16) studied some of the nutrients in ogi. Some of his data are presented in Table IV.

According to Banigo and Muller (31), besides corn, sorghum and millet may also be used to produce ogi. The total solids in corn and sorghum ogi were about 83% of the original dry weight, whereas they were as low as 61% in millet. Using these three cereals, there was no significant change in most of the amino acids except for lysine, the limiting amino acid in cereals, which was reduced by about 50%. Table V is taken directly from the results obtained by Banigo and Muller (31).

In a second paper, Banigo and Muller (26) studied the 11 acids formed during the ogi fermentation and found that lactic, acetic, and butyric acids were the dominant ones. The lowest pH was found to occur at about two days when maize was the fermented substrate. The preferred pH of the product is from 3.5 to 3.7.

MAHEWU (MAGOU)

This is a South African beverage, similar to ogi, that is now manufactured on a modern inudstrial scale as a dry product (19,28,32). Mahewu is a sour, nonalcoholic beverage consumed extensively by the Bantu and plays an important role in their diet. The Bantu generally prefer a product with about 8% solids content and an acidity of 0.4 to 0.45% lactic acid. Volatile fatty acids, such as acetic and butyric, are unacceptable. Alcohol should not be present in concentrations higher than 0.5%. The Bantu prepare this food by boiling a thin maize porridge containing about 8 to 10% solids. After boiling, the liquid is cooled to 25 C and a small quantity of wheat flour (about 5% of the maize meal used) is added. This is the source of the inoculum and therefore differs from the preparation of ogi, although the results are the same, the production of a soured maize product. The inoculated liquid is placed in a warm, sunny place to turn sour. The main microorganism in native-made mahewu is *Streptococcus lactis*. Disadvantages of the native process are: acidulation takes too long; acid is irregularly formed; volatile fatty acids are formed; and *E. coli* may develop in the product. Usual pH of the product is about 3.5.

The industrial process is somewhat different and is outlined in Figure 4 as described by Schweigart and deWit (28) and Schweigart and Fellingham (19).

These authors found that at 45 C with wheat flour and *L. delbrueckii* the correct acidity (pH 3.5) was attained in only 16 hr, and almost all the acid was lactic. Wheat flour is necessary, since it has a stimulating effect on the souring process. *L. bulgaricus* may also be used. The low protein product can be enriched by adding skimmed milk or whey powder, soybean flour, food yeast, or fish flour. Wheat bran may be substituted for wheat with excellent results, provided it is not heated. Its beneficial effect is believed to be from the enzymes present, since heating of either wheat or wheat bran causes loss in their ability to stimulate acid production by the bacteria.

If the mahewu is heated to destroy the enzymes, the product may be kept at room temperature for at least 1 year. The powder may be reconstituted with water. Since the product is used by laborers in heavy industry, its nutritive value was examined. These studies on mahewu showed it to contain 7 to 9% protein of a low quality when unfortified. The initial vitamin B_1 level is almost unchanged, and the B_2 remains intact. Niacin present in a bound form in maize is freed by autoclaving and doubles in value. For more details, the reader should consult Schweigart et al. (32).

The modern industrial process for preparing magou, as I saw it several years ago, operates as follows: magou is prepared by the fermentation of coarsely ground white corn meal (maize). Pure cultures of *Lactobacillus* used in this fermentation were isolated from native magou. The culture, which is not pure, is started in coarse whole wheat flour. The corn meal to be fermented is sterilized for 1 hr plus a holding time of about 45 min to give a thick slurry of about 9% solids. The thick corn slurry is inoculated at 47 to 52 C with the mixed starter culture. After inoculation, the fermentation is allowed to proceed in open 1000-gallon steel tanks without heat control and with little or no aeration for about 22-24 hr. The pH of the fermenting corn slurry drops to between 3.65 and 3.95. Probably because mixed cultures are used, no problem with phage ever has occurred. The mash from the fermentation tanks is mixed with defatted soybean meal, sugar, whey or buttermilk powder, and yeast. The soybean meal used contains at least 52% protein. After thorough mixing of all the ingredients, the mix is spray dried. In 1970, this product sold for about 10 cents a lb in 50-lb bags. The final product has a moisture content of 3.5-4% and can be kept in a dry state for a year. Thus, the products can be transported long distances and preparation requires only the addition of water. Magou is used principally for feeding miners and other workers employed in heavy industry. It can be taken into the mines and reconstituted at the point of consumption.

KAFFIR BEER (BANTU BEER, SORGHUM BEER, MQOMBOTHI)

Kaffir beer has a number of names (Zulu, utshwala, Sesuto, joala, Eastern Cape, utywala) and is the drink of the Bantu people of South Africa. This beer, which is consumed as a food, is produced by both modern industrial and village processes and is quite different from European beer. Kaffir beer is pink and opaque because of the suspended solids. It has a pleasant yeasty odor with a slightly fruity tang not unlike yogurt and is bubbling because it is still in an active fermentation state. The corn grits in the beer give it a scratchy or mealy consistency that may not appeal to Western people. The pinkish color arises from the red sorghum used in malting. Kaffir beer is always consumed in an active state of fermentation and, hence, can be kept for only a few days.

The production of Kaffir beer by the industrial process for 1974-1977 is shown in Table VI (Dr. J.A. deVilliers, personal communication, 1978). The current average price is 15 cents per liter for pack (polythenelined cardboard) and 10 cents for bulk beer, which is less than half the price of milk or Coca Cola. It is estimated that production of home-brewed Kaffir beer about equals that produced industrially (1).

The modern method of producing Kaffir beer is shown in Figure 5. Some plants have a 4.5-million gallon capacity per month. Part of this production goes into containers

Sorghum (Kaffir corn, red varieties)
↓
Cleaned and washed
↓
Steeped 8 to 24 hr
↓
Germinated 5 to 7 days at 25 to 30 C in depth of 3 to 4 ft and watered for first 3 days
↓ ← Grain must be turned and cool air used to reduce heat
Malt (60-65% moisture: roots and shoots 1-2 in. in length)
↓
Dried at 50 to 60 C
↓
Ground
↓
Finished sorghum malt (beta-amylase, 30 to 40%; alpha-amylase, 60 to 70%)
↓ ← Water
↓ ← 10% Inoculum from previous batch
Fermentation, 48 to 50 C, 8 to 16 hr (fermentation equals one-third volume of beer)
↓
Finished sour mash, pH 3 to 3.3
↓
Pumped to cooker and diluted with 2 vol of water
↓ ← Corn grits (occasionally sorghum grits may be added)
Cooked 2 hr at atmospheric pressure
↓
Cooled to 60 C
↓
Sorghum malt added
↓
Held for 1-1/2 to 2 hr
↓
Cooled to 30 C
↓ ← Top fermenting yeast (*Saccharomyces cerevisiae* NRRL Y-7184) as pure culture
Strained to remove coarse particles of malt husks
↓
Fermentors, 30 C, 8 to 24 hr if bulk beer; 0 to 6 hr if sold in cartons
↓
Finished Kaffir beer

FIG. 5. Kaffir beer fermentation.

similar to milk cartons except small openings are left for escape of gas, and the rest is bulk beer delivered by stainless-steel tank trucks directly to the beer halls. Details about the malting, brewing, and inoculation can be found in papers by Novellie (1,18), Schwartz (33), and van der Walt (34).

The number of breweries can be divided into three classes: three large breweries with annual production of 17 million or more imperial gallons each; 16 breweries with an annual capacity of 1 to 7 million imperial gallons; and 50 minor producers who annually produce less than 1 million imperial gallons.

Bantu beer contains lactic acid but must not contain acetic acid. The natives' acute sense of taste makes acetic acid distasteful to them. If the beer is sour and contains little alcohol, this appears to be still very acceptable. The low pH, of course, prevents other types of bacteria from growing but allows yeast fermentation to proceed rapidly. The acid softens the protein endosperm to allow release of starch, a major ingredient in the beer. It provides the sugars for fermentation but also is partially gelatinized. This helps keep the ungelatinized starch and grain particles in suspension to give the right appearance and mouthfeel.

Because of the shift from sorghum grits to corn grits, changes have occurred in the vitamin content of the beer. Corn is used because it is cheaper than sorghum. Vitamin content data are not reliable and need to be restudied for the modern fermentation.

The Bantu industry is unique in several respects, according to Dr. Novellie: (a) It is the only large modern industry founded on a tribal art. (b) The industry is in the hands of local authorities and not private industry. License to brew Bantu beer is granted to each municipality by the Federal government. (c) Profits are controlled by the government, and the greater amount of profit goes for Bantu development projects. (d) Sorghum malt and yeast inoculum is made by private industry and sold to the municipal breweries. Thus, in 1965-1966, the municipal breweries bought 244,500 lb of dried yeast for pitching. The yeast in the beer is never removed, because it is consumed in a raw state with the liquid. The yeast used originally came from Dr. J.P. van der Walt's isolation of yeast from a good native fermentation. He regularly makes cultures available to the companies that prepare the dry yeast.

The range in analyses of Bantu beer is given in Table VII. Modern Bantu beer research started at the Council for Scientific and Industrial Research (CSIR) in 1954 with no outside financial support. Later support came from the municipalities who donated money to the Institute of Administration of non-European Affairs, and this office funded CSIR research. Later, the government placed a 0.75 cent per gallon levy on sales of Kaffir beer to finance research at CSIR.

In this brief account of fermented vegetable foods made by fermentation, I have mentioned the multitude of products in Africa, the Middle East, and India. These are made principally from cereals by bacterial fermentation. Further development of these products and their fortification with protein, such as soybean meal, offer a real challenge. In any such attempt to do this, I think it would be wise to study the development of the Kaffir beer industrialization

TABLE VI

Production of Kaffir Beer by Industrial Process

Year	Bulk beer (million liters)	Park beer (million liters)	Total value (million rand)
1974	425	518	68
1975	409	504	76
1976	342	501	82
1977	348	531	90

Home production may be nearly as much.

TABLE VII

Analytical Data for Bantu Beer

Determination	Range of analysis	Average
pH	3.2 - 3.9	3.5
Lactic acid, mg %	164 - 250	213
Volatile acidity as g acetic acid/100 ml	0.012 - 0.019	0.016
Total solids, %	2.6 - 7.2	4.9
Insoluble solids, %	1.6 - 4.3	2.3
Alcohol, % by weight	2.4 - 4.0	3.2
Nitrogen, %	0.065 - 0.115	0.084

in Africa.

REFERENCES

1. Novellie, L., "Beverages from Sorghum and Millets," International Association for Cereal Chemists, Symposium, Vienna, Austria, pp. 73-77, 1976.
2. van Veen, A.G., L.R. Hackler, K.H. Steinkraus, and S.K. Mukherjee, J. Food Sci. 32-339 (1967).
3. Batra, L.R., and P.D. Millner, Mycologia 66:942 (1974).
4. Ramakrishnan, C.V., Fourth Annual Research Report on Study of Indian Fermented Foods, pp. 1-77, 1977.
5. Rajalakshmi, R., and K. Vanaja, Br. J. Nutr. 21:467 (1967).
6. Ghosh, G.R., Sci. Cult. 23:557 (1958).
7. Batra, L.R., and P.D. Millner, Dev. Ind. Microbiol. 17:117 (1976).
8. Platt, B.S., Food Technol. (Chicago) 18:68 (1964).
9. Stewart, R.B., and A. Getachew, Econ. Bot. 16:127 (1962).
10. Tschekan, L., Cent. f. Bakt. Ser. II. 77:151, 78:74 (1929).
11. Morcos, S.R., S.M. Hegazi, and S.T. El-Damhoughy, J. Sci. Food Agric. 24:1157 (1973).
12. Morcos, S.R., S.M. Hegazi, and S.T. El-Damhough, Ibid. 24:1153 (1973).
13. Miracle, M.P., in "Food Technology the World Over," Vol. 2, Chapter 16, Edited by M.S. Peterson and D.K. Tressler, p. 107, 1965.
14. Stanton, W.R., and A. Wallbridge, Process Biochem. 4:45 (1969).
15. Oke, O.L., Nature 212:1055 (1966).
16. Akinrele, I.A., J. Sci. Food Agric. 21:619 (1970).
17. Faparusi, S.I., Ibid. 21:79 (1970).
18. Novellie, L., Wallerstein Lab. Commun. 31:17 (1968).
19. Schweigart, F., and S.A. Fellingham, Milchwissenschaft 18:241 (1963).
20. Doidge, E.M., Transvaal Dep. Agric., Agric. Sci. Bull. 5:1 (1910).
21. Quin, P.J., S.Afr. Med. J. 38:969 (1964).
22. Yen, D.E., Econ. Bot. 13:319 (1959).
23. Cerkez, S.C., J. Brew. 5:329 (1899).
24. van Veen, A.G., D.C.W. Graham, and K.H. Steinkraus, Arch. Latinoam. Nutr. 18:363 (1968).
25. Ulloa, M., Bot. Soc. Mex. Mic. 8:17 (1974).
26. Banigo, E.O.I., and H.G. Muller, J. Sci. Food Agric. 23:101 (1972).
27. Aucamp, M.C., J.T. Grieff, L. Novellie, B. Papendick, H.M. Schwartz, and A.G. Steer, Ibid. 12:449 (1961).
28. Schweigart, F., and J.P. de Wit, "Preparing and Drying of Mahewu and Its Nutritional Value," Food Industries of South Africa, May/June, 1960, p. 3.
29. Amoa, B., and H.G. Muller, Cereal Chem. 53:365 (1976).
30. Steinkraus, K.H., A.G. van Veen, and D.B. Tiebeau, Food Technol. (Chicago) 21:916 (1967).
31. Banigo, E.O.I., and H.G. Muller, Can. Inst. Food Sci. Technol. 5:217 (1972).
32. Schweigart, F., W.E.L. van Bergen, S.G. Wiechers, and J.P. de Wit, S. Afr. Counc. Sci. Ind. Res., Res. Rep. No. 167:1 (1960).
33. Schwartz, H.M., J. Sci. Food Agric. 7:101 (1956).
34. van der Walt, J.P., Ibid. 7:105 (1956).